Federal State Autonomous Educational Institution of Higher Education
Peoples' Friendship University of Russia named after Patrice Lumumba

Academy of Engineering
(name of the main educational unit (MEU) that developed the educational program of higher education)

WORKING PROGRAM OF THE DISCIPLINE

ARTIFICIAL NEURAL NETWORKS (DEEP LEARNING)
(name of discipline/module)

Recommended for the field of study/specialty:

27.04.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the field of study/specialty)

The discipline is mastered within the framework of the implementation of the main professional educational program of higher education (EP HE):

Artificial Intelligence, Machine Learning, and Space Science
(name (profile/specialization) of the educational institution of higher education)

2026

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Artificial Neural Networks (Deep Learning)" is part of the Master's program "Artificial Intelligence, Machine Learning, and Space Sciences" in the 27.04.04 "Control in Technical Systems" program and is studied in the second semester of the first year. The course is offered by the Department of Mechanics and Control Processes. It consists of six sections and 15 topics and focuses on methods for constructing automatic control systems based on artificial neural networks and mastering methods for solving basic control problems using neural networks.

The purpose of mastering the discipline is to teach students methods of constructing artificial neural networks.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline "Artificial Neural Networks (Deep Learning)" aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies developed in students while mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
UC-1	Capable of carrying out a critical analysis of problematic situations based on a systems approach and developing an action strategy	UC-1.1 Analyzes the task, identifying its basic components; UC-1.2 Defines and ranks the information required to solve the given problem; UC-1.3 Searches for information to solve a given problem using various types of requests;
PC-1	Able to formulate goals and objectives of scientific research in the field of aerospace systems management, and select methods and means for solving professional problems	PC-1.1 Knows the methods and means of solving scientific research problems in the field of artificial intelligence systems and robotic systems; PC-1.2 Able to formulate the goals and objectives of scientific research in the professional field; PC-1.3 Proficient in techniques for formulating the goals and objectives of scientific research, and knows how to select methods and means for solving problems of professional activity.
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	PC-2.1 Knows modern theoretical and experimental methods used to develop mathematical models of studied objects and processes of professional activity; PC-2.2 Able to determine the effectiveness of the methods used to develop mathematical models of the objects and processes under study; PC-2.3 Has mastered modern theoretical and experimental methods for developing mathematical models of objects and processes of professional activity in the field of study.

3. PLACE OF THE DISCIPLINE IN THE STRUCTURE OF THE EDUCATIONAL EDUCATIONAL INSTITUTION

Discipline "Artificial Neural Networks (Deep Learning)" refers to the part formed by the participants of educational relations of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Artificial Neural Networks (Deep Learning)".

Table 3.1. List of components of the educational program of higher education that contribute to the achievement of the planned results of mastering the discipline

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
UC-1	Capable of carrying out a critical analysis of problematic situations based on a systems approach and developing an action strategy	History and Methodology of Science;	Research work / Scientific research work; Undergraduate Training; *Artificial Neural Networks (Reinforcement Learning)***; *Artificial Neural Networks (Reinforcement Learning)***;
PC-1	Able to formulate goals and objectives of scientific research in the field of aerospace systems management, and select methods and means for solving professional problems		*Artificial Neural Networks (Reinforcement Learning)***; Research work / Scientific research work; Undergraduate Training;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	History and Methodology of Science; Virtual Reality and Computer Vision; Information Technology in Mathematical Modeling;	*Research work / Scientific research work;* *Undergraduate Training;* *Dynamics and Control of Space Systems;* *Artificial Neural Networks (Reinforcement Learning)***;* *Geoinformation Systems and Applications;*

* - filled in accordance with the competency matrix and the SUP EP HE

** - elective courses/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF EDUCATIONAL WORK

The total workload of the course “Artificial Neural Networks (Deep Learning)” is 5 credits.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,**academic hours		**Semester(s)**
			2
Contact work, academic hours	*72*		*72*
Lectures (LC)	36		36
Laboratory work (LW)	36		36
Practical/seminar classes (SC)	0		0
Independent work of students, academic hours	*81*		*81*
Control (exam/test with assessment), academic hours	*27*		*27*
Total complexity of the discipline	**academic hours**	***180***	*180*
	credit	***5***	*5*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of academic work

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 1	Basic concepts. Typology of problems solved by machine learning methods. Multilayer perceptron	1.1	Definitions, history of development and main trends of artificial intelligence.	Artificial intelligence as a field of science concerned with creating systems capable of performing tasks requiring human intelligence. History of development: emergence in the 1950s, periods of AI winter, revival with the advent of machine learning methods. Main trends: deep learning, large language models, generative neural networks, explainable artificial intelligence.	LC, LW
		1.2	Biological neuron and its mathematical model. Types of activation functions. Neural networks and their classification. Mathematical models of specialized neurons.	Biological neuron as a cell that receives and transmits electrical signals through dendrites, cell body, and axon. Mathematical model of a neuron: summation of weighted input signals, addition of bias, application of a non-linear activation function. Types of activation functions: threshold, sigmoid, hyperbolic tangent, rectified linear unit. Classification of neural networks: by architecture feedforward and recurrent, by learning method supervised and unsupervised.	LC, LW
		1.3	Multilayer neural networks. Representation of regression, approximation, identification, control, data compression problems in a neural network logical basis. Multilayer perceptron.	Representation of regression, approximation, identification, control, and data compression tasks in a neural network logical basis. Multilayer perceptron as a neural network with one or more hidden layers between input and output layers. Capability of the multilayer perceptron to approximate any continuous function. Applications for classification, regression, and forecasting.	LC, LW
Section 2	Evolutionary Teaching Methods	2.1	Backpropagation algorithm and its modifications.	Backpropagation algorithm as the primary learning method for multilayer perceptrons. Algorithm stages: forward pass to compute network outputs, error calculation at the output layer, backward pass to propagate error to previous layers, weight adjustment using the gradient of the error function. Modifications of the algorithm: momentum method for accelerating convergence, adaptive learning rate methods, methods using second derivatives.	LC, LW
		2.2	Selecting optimal network parameters	Problem of selecting the number of layers and the number of neurons in each layer. Selection of learning rate, momentum, and number of training epochs. Overfitting problem: when the network memorizes training examples but loses generalization ability. Methods for combat overfitting: regularization, early stopping, dropout, increasing training data size. Cross-validation for eval-	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				uating network generalization ability.	
Section 3	Types of neural networks	3.1	Neural network with general regression.	General regression neural network as a network designed for function approximation and regression analysis. Principle of operation: using radial basis functions to approximate the target function. Network structure: input layer, radial layer, summation layer. Fast training but large memory requirements for storing training examples.	LC, LW
		3.2	Probabilistic neural network.	Probabilistic neural network as a network for classification tasks based on probability density estimation. Principle of operation: using kernel density estimates for each class. Network structure: input layer, summation layer for each class, output layer selecting the class with maximum probability. Advantages: fast training, robustness to outliers, ability to obtain posterior probabilities.	LC, LW
		3.3	Neural networks with radial basis functions.	Radial basis function networks as networks using radial functions in the hidden layer that depend on the distance between the input vector and the function center. Network structure: input layer, hidden layer with radial elements, output linear layer. Methods for center selection: random selection, clustering, supervised learning. Applications for function approximation and classification.	LC, LW
		3.4	Neural network and Kohonen self-organizing maps	Self-organizing maps as unsupervised neural networks designed for visualizing multidimensional data in a low-dimensional space. Principle of operation: competitive learning where the winning neuron adjusts its weights and the weights of neighboring neurons. Map topology: rectangular or hexagonal grid. Applications for clustering, dimensionality reduction, and data visualization.	LC, LW
Section 4	Evolutionary teaching methods	4.1	Backpropagation algorithm and its modifications. Multilayer perceptrons. Selection of optimal network parameters	Backpropagation algorithm as a gradient-based learning method. Problem of initial weight selection: importance of proper initialization for convergence. Modifications of the algorithm: conjugate gradient method, Levenberg-Marquardt method, adaptive learning rate algorithms. Problem of local minima on the error surface. Methods for escaping local minima: adding noise to the gradient, random restart training, stochastic gradient descent. Network architecture selection as a separate optimization task.	LC, LW
Section 5	Feedback neural networks	5.1	Hopfield neural networks. Neural network methods for solving optimization-combinatorial problems. Hamming neural networks.	Hopfield network as a recurrent network with feedback connections where each neuron is connected to all others. Energy function property: the network evolves toward an energy minimum, cor-	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
			Pattern recognition using distances.	responding to pattern retrieval. Application for associative memory: noise-corrupted pattern restoration. Solving optimization-combinatorial problems using the traveling salesman problem as an example. Hamming network as a network that computes the Hamming distance between the input vector and reference patterns. Pattern recognition using distance metrics.	
		5.2	Bidirectional Associative Neural Networks. Perceptron-Based Feedback Neural Networks	Bidirectional associative neural networks as networks that perform mapping between two sets of vectors in both forward and backward directions. Network structure: two layers of neurons connected by bidirectional connections. Application for associative memory of pattern pairs: retrieving the associated pair from one pattern. Recurrent neural networks based on perceptrons: recurrent versions of multilayer perceptrons.	LC, LW
Section 6	Specialized neural networks	6.1	Deep neural networks.	Deep neural networks as networks with many hidden layers are capable of extracting hierarchical data representations. Vanishing gradient problem in training deep networks. Methods for overcoming this: unsupervised layer-wise pre-training, rectified linear unit activation functions, batch normalization, skip connections.	LC, LW
		6.2	Convolutional neural networks.	Convolutional neural networks as networks specifically designed for processing grid-structured data such as images. Key operations: convolution with filters for feature extraction, pooling for dimensionality reduction, channel concatenation. Layer types: convolutional layers, pooling layers, fully connected layers. Advantages over fully connected networks: local connectivity, shared weights, translation invariance. Applications for object recognition, image segmentation, and edge detection.	LC, LW
		6.3	Recurrent networks.	Recurrent neural networks as networks with cyclic connections that maintain an internal state over time. Ability to process variable-length sequences. Problem of long-term dependencies and gradient vanishing. Architectures with long short-term memory and gated recurrent units that solve the vanishing gradient problem through special gating mechanisms. Applications for machine translation, time series analysis, text generation, and speech recognition.	LC, LW

* - to be completed only for FULL-TIME education: LC – lectures; LW – laboratory work; SC – practical/seminar classes.

6. LOGISTIC AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support for the discipline

Audience type	Equipment of the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	A lecture hall equipped with specialized furniture, a whiteboard (screen), and multimedia presentation equipment.	
Computer class	A computer room for conducting classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with personal computers (in the amount of ____ units), a board (screen) and technical means for multimedia presentations.	
For independent work	A classroom for independent student work (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the classroom for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. S. Khaikin. Neural Networks: A Complete Course. 2nd ed. Moscow, Williams, 2006.

2. A.N.Vasiliev, D.A.Tarkhov. Neuronal modeling. Principles. Algorithms. Applications. SPb.: Publishing House Polytechnic. Univ., 2009. ISBN 978-5-7422-2272-9

3. Mohamad H. Hassoun. Fundamentals of Artificial Neural Networks.MIT Press, Cambridge, Massachusetts, 1995.

4. D.A. Tarkhov. Neural Networks. Models and Algorithms. Moscow, Radio Engineering, 2005. (Scientific series "Neurocomputers and Their Applications", ed. A.I. Galushkin. Book 18.)

5. CCAggarwal. Neural Networks and Deep Learning. A Textbook. Springer International Publishing

Further reading:

1. DERumelhardt, GEHinton, RJWilliams. Learning representations by back-propagating errors.Nature, 1986, V.323, pp.533-536.

2. Caudill, M. The Kohonen Model. Neural Network Primer. AI Expert, 1990, 25-31.

3. J. J. Hopfield. Neural networks and physical systems with emergent collective computational abilities. Proceedings of National Academy of Sciences of USA, 1982, V.79, No.8, pp.2554-2558.

Resources of the information and telecommunications network "Internet":

1. RUDN University Electronic Library System and third-party electronic library systems to which university students have access based on concluded agreements

- RUDN University Electronic Library System – RUDN University Electronic

Library System https://mega.rudn.ru/MegaPro/Web

- Electronic Library System "University Library Online" http://www.biblioclub.ru
- EBS Yurayt http://www.biblio-online.ru
- Electronic Library System "Student Consultant" www.studentlibrary.ru
- EBS “Knowledge” https://znanium.ru/

2. Databases and search engines

- Sage https://journals.sagepub.com/
- Springer Nature Link https://link.springer.com/
- Wiley Journal Database https://onlinelibrary.wiley.com/
- Scientometric database Lens.org https://www.lens.org

Educational and methodological materials for independent work of students in mastering a discipline/module:*

1. Lecture course on the subject "Artificial Neural Networks (Deep Learning)".

* - all teaching and methodological materials for independent work of students are posted in accordance with the current procedure on the discipline page in TUIS!

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